PLEISTOCENE LACUSTRINE BASIN OF THE EAST DOMAIN OF GUADIX-BAZA BASIN (GRANADA, SPAIN): SEDIMENTOLOGY, CHRONOSTRATIGRAPHY, AND PALAEOENVIRONMENT

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ABSTRACT

We present the study of the lacustrine deposits of the eastern part of the Guadix Baza basin (GBE), an intramontanous basin which remained isolated from erosive conditions until upper Middle Pleistocene times. The facies distribution shows a clear centripetal pattern, with alluvial fan systems reaching the GBE through still visible gorges, all of them which were fed by run-off as well as groundwater from karst with dissolved sulphates from marine Miocene and Upper Triassic age evaporites. A complex system of sandy beaches, mud flat playa and marginal lacustrine sands connected central lacustrine environments and marginal alluvial fans (sheet flow deposits). After field measurements, paleomagnetism determinations and amino acid racemisation, a "composite-stratotype-section" was established that provided a time-and-space framework for the GBE lacustrine deposits. Unfortunately, all fossils in the central lacustrine facies were destroyed by gypsum diagenesis.

In the "composite-stratotype-section" (average sedimentation rate of 22 cm/ka) samples were collected at 50 cm intervals. After sample washing, sieving, and ostracode recovery, an almost continuous ostracode species log was obtained. The ostracode record show abrupt and frequent changes in lake water salinity occurred during the Lower Pleistocene, and high salinity during the upper part of the Lower Pleistocene and the first half million years of the Middle Pleistocene prevailed *(Cyprideis torosa* (Jones) *dominance).* The uppermost part of the section, characterized by highly saline conditions, is located in the Orce Corridor, where geological data indicate restricted basin geometry and local hydrological input from saline groundwater. Further studies are needed to investigate the role of these conditions in the origin of these high salinity values.

Keywords: Guadix-Baza basin, palaeosalinity, Pleistocene, magnetostratigraphy, aminostratigraphy, limnogeology, Spain

RESUMEN

Se presenta el estudio de los depósitos lacustres de la parte este de la Cuenca de Guadíx Baza (GBE), una cuenca intramontañosa que permaneció preservada de la erosión hasta la parte superior del Pleistoceno medio. La distribución de facies muestra una clara distribución centrípeta con sistemas de abanicos aluviales que alcanzaron la GBE a través de cañones todavía hoy visibles, aunque también se produjeron aportes de exutorios kársticos con sulfatos disueltos de las evaporitas del Mioceno y Triásico superior. Un sistema complejo de playas arenosas, llanuras fangosas y arenas lacustres marginales conectaba los ambientes lacustres centrales y los depósitos de manto de arroyada de los abanicos aluviales. A partir de trabajo de campo, paleomagnetismo y racemización de aminoácidos en moluscos y, principalmente, en ostrácodos se ha establecido una sección estratigráfica tipo compuesta. El principal objetivo de este trabajo es establecer las relaciones espacio-temporales de los depósitos lacustres de la GBE aunque se evitó trabajar en las facies lacustres centrales, ya que en ellas todos los restos fósiles habían sido destruidos por la yesificación.

En la seccion estratigráfica tipo (con una velocidad media de sedimentación de 22 cm/ka) se tomó una muestra cada 50 cm. Se obtuvo la curva de variación de especies y se han documentado cambios de salinidad muy frecuentes durante el Pleistoceno inferior, mientras que en la parte superior del Pleistoceno inferior y en el primer medio millón de años del Pleistoceno medio predominaron condiciones de alta salinidad (dominancia de *Cyprideis torosa* (Jones). El predominio de esta especie en la parte superior del registro necesitará análisis posteriores, isotópicos, ya que en el área de Orce las condiciones locales como la restricción geométrica del Corredor de Orce y la presencia de fuentes salinas podría haber condicionado este hecho.

Palabras clave: cuenca de Guadix-Baza, paleosalinidad, Pleistoceno, magnetoestratigrafía, aminoestratigrafía, limnogeología, Spain

1. INTRODUCTION

Among all the Alpine basins located on the Iberian Peninsula, the Guadix-Baza basin appears to be a very singular realm where almost "continuous" continental sedimentation took place from the Pliocene until ca. 300 ka BP, a period commonly characterised in Europe by erosive processes. The aim of this paper is to describe the stratigraphy and sedimentology of the eastern part of the Guadix-Baza basin (GBE), where a large number of palaeontological localities, some with abundant lithic tools, have been studied. A chronostratigraphic framework is also established based on palaeomagnetism, amino-acid racemization, and paleoenvironmental evolution of ostracode species assemblages.

2. GEOGRAPHICAL AND GEOLOGICAL SETTING

The Guadix-Baza basin (Fig.1) is a long and narrow basin (4,500 km^2) with its major axis oriented NE-SW within the Betic Range. According to Pous et al. (1995), the Guadix-Baza basin is nested between the Internal and External Zone of the Betic Range.

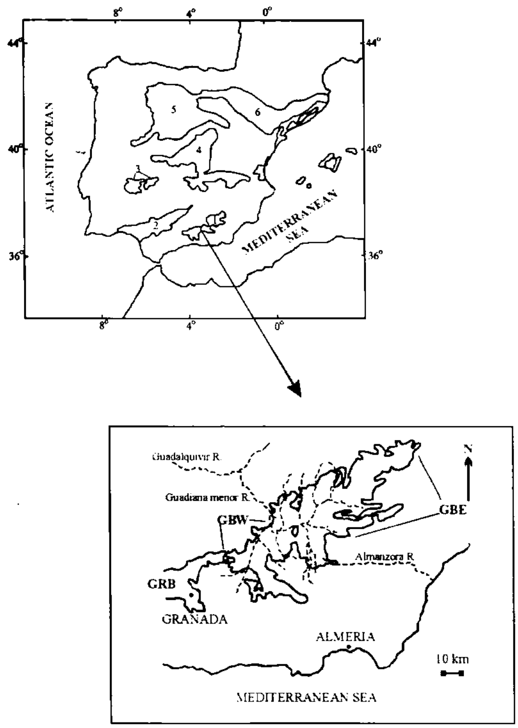


Figure 1. Geographical overview of the Guadix-Baza basin and other Iberian Cainozoic basins. 1: Guadix-Baza basin. 2: Guadalquivir basin. 3: Guadiana basin. 4: Tajo basin. 5: Duero basin. 6: Ebro basin. Other minor basins are not represented.

Figura 1. Situación geográfica de la cuenca de Guadix-Baza y otras cuencas cenozoicas. 1: cuenca de Guadix-Baza. 2: cuenca del Guadalquivir. 3: cuenca del Guadiana. 4: cuenca del Tajo. 5: cuenca del Duero. 6: cuenca del Ebro. Otras cuencas menores no se han representado.

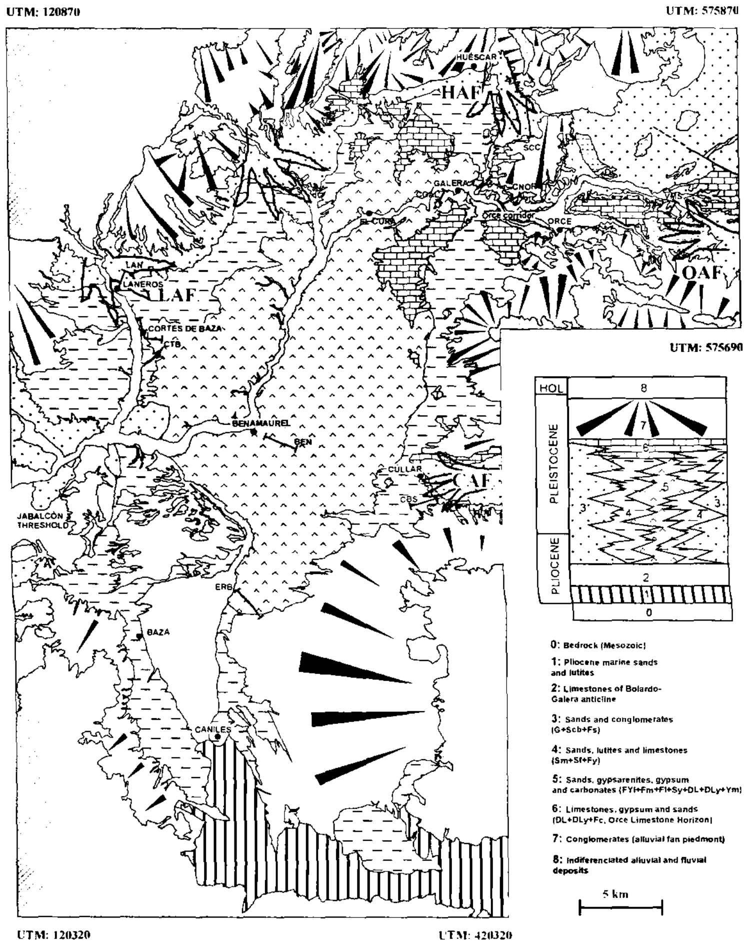


Figure 2. Simplified geological map of the east (Baza) domain of Guadix-Baza basin (GBE). LAF=Laneros Alluvial Fan, OAF= Orce Alluvial Fan, HAF= Huéscar Alluvial Fan, CAF= Cúllar Alluvial Fan. CTB: Cortes de Baza; CNOR: Norte de Orce; CGAL: Cementerio de Galera; LAN: Laneros; BEN: Benamaurel; SCC: San Clemente channel; VMS: Venta Micena; ERB: East of río Baza; CBS: Cúllar-Baza stratigraphical sections

Figura 2. Mapa geológico simplificado del sector este (Baza) de la cuenca de Guadix-Baza (GBE). LAF= Abanico aluvial de Laneros, OAF= Abanico aluvial de Orce, HAF= Abanico aluvial de Huéscar, CAF= Abanico aluvial de Cúllar. CTB: Cortes de Baza; CNOR: Norte de Orce; CGAL: Cementerio de Galera; LAN: Laneros; BEN: Benamaurel; SCC: Canal de San Clemente; VMS: Venta Micena; ERB: Este de río Baza; CBS: Cúllar-Baza

The Internal Zone consists of four stacked nappe complexes containing rocks of Triassic age or older. The External Zone is composed of allochthonous foreland and Iberian Plate continental margin material; this zone comprises a deformed wedge of dominantly marine rocks ranging from Mesozoic to Lower Miocene age along with plastic evaporite and mudstone layers of Triassic age (Banks and Warburton, 1991).

The Guadix-Baza basin is a foreland basin formed during the Alpine Orogeny from the Upper Tortonian-Lower Pliocene (Vera, 1970b; Soria, 1996). The presence of backthrusted Triassic evaporites and mudstones in this basin was responsible for local rock strain during the Pliocene and Pleistocene. The basin fill contains sediments from the Pliocene until the Recent (Fig. 2). By the time of the Upper Tortonian, sedimentation was continental in origin with the deposition of alluvial and palustrine-lacustrine sediments in two well-marked depocentres divided by the Jabalcón threshold: Guadix or west domain (GBW) and Baza or east domain (GBE). During the upper Middle Pleistocene, the GBE experienced an erosional episode documented by a general progradation of alluvial fan systems towards the central part of the basin and the erosion of all the preceding continental Pliocene and lower Middle Pleistocene stratigraphical sequences. Faults affecting underlying Mesozoic rocks were responsible for local tilting, which allowed for preservation of the upper Middle Pleistocene stratigraphy. These faults controlled the direction of streams and their related valleys.

The sediment fill of the GBE comprises gravels/conglomerates, sands/sandstones, lutites, carbonate rocks and gypsum. The source rocks at the north rim of the basin are limestones and dolostones of Mesozoic age as well as evaporites and mudstones of Triassic age while in the southern edge metamorphic rocks (marble, schist) are also present. Recycling of ancient evaporites has affected sedimentation as evidenced by the saline springs which feed rivers today in a way common in all Iberian cenozoic basins (Ortí et al., 1988). The detrital gypsum deposits are made of intraclasts of intrabasinal origin in the way proposed by Sanz et al. (1994).

3. SEDIMENTOLOGY

Former sedimentological and stratigraphical studies of GBE were carried out by Vera (1969, 1970a, 1970b), Peña (1985), Vera et al. (1984), Soria et al. (1987), and Gibert et al (1992).

The sedimentary evolution of the basin was influenced greatly by its irregular shape and the unequal inputs of the catchments feeding the alluvial fans which display different centripetal patterns (Fig. 2) from the basin borders to the central portion of the basin. The different alluvial fan systems distinguished include the most important one, the Laneros Alluvial Fan (LAF) (Fig. 2), which can be described as a high-efficiency alluvial fan or as a "humid alluvial fan" in the sense proposed by Collinson (1996).

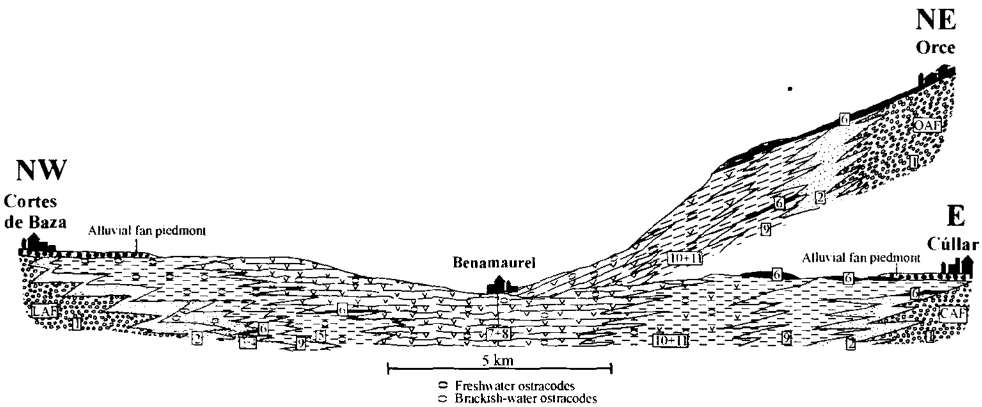


Figure 3. Schematic fence diagram of facies distribution in GBE. 1: gravel/conglomerates (G); 2: channeled sand/sandstones and gravel/conglomerates (Scb); 3: Massive sands/sandstones (Sm); 4: Fossiliferous sands/sandstones (Sf); 5: massive lutites (Fm), laminated lutites (Fl); 6: carbonate lutites-marls (Fc), dolomitic limestones and limestones (DL), dolomitic limestones and limestones with gypsum (DLy); 7: laminated lutites and gypsum (Fyl); 8: massive gypsum (Ym); 9: sandy/gravelly lutites (Fs); 10: lutites with displacive gypsum (Fy); 11: gypsiferous sands/sandstones (Sy).

Figura 3. Panel de correlación de facies en GBE. 1: gravas/conglomerados (G); 2: arenas/areniscas y gravas/conglomerados canalizados (Scb); 3: arenas/areniscas masivas (Sm); 4: arenas/areniscas fosilíferas (Sf); 5: lutitas masivas (Fm), lutitas laminadas (Fl); 6: lutitas carbonatadas-margas (Fc), calizas dolomíticas y calizas (DL), calizas dolomíticas y calizas con yeso (DLy); 7: lutitas laminadas y yeso (Fyl); 8: yeso masivo (Ym); 9: lutitas arenosas/con grava (Fs); 10: lutitas con yeso intrasedimentario (Fy); 11: arenas/areniscas yesíferas (Sy).

The LAF interfingers with a lacustrine system in a typical radial facies distribution (Fig. 3) with some exceptions (Fig. 4a), though a clear lacustrine expansion is documented towards the top of LAF through the lack of marginal lacustrine sand facies and a compression of fan facies. Other identified alluvial fan systems are: Huéscar Alluvial Fan (HAF), Orce Alluvial Fan (OAF) and Cúllar Alluvial Fan (CAF) (Fig. 2). In these cases, the alluvial fan-lake relationship is radially distributed but not well-commingled (Fig. 3,4b). Alluvial fan-lake deposits in the GBE differ markedly from those found in the GBW. In the western part of the basin, subsidence ratios were much higher, so that sediment thickness in the GBE on the shallow "Mesozoic bedrock" (IGME, 1988) were significantly thinner.

3.1.Facies description

Due to the large number of facies which can be distinguished in the GBE, the facies, their descriptions, and interpretations are listed in Table 1.

3.2. Facies interpretation

All the described facies can be grouped into three different depositional settings sensu Rodríguez-Aranda et al (1991): alluvial fan (G, Scb), transitional environment (Fm, Fs, Fy) and shallow-lacustrine realm (Sm, Sf, Sy, Fc, Fyl, Fy, Ym, DL, DLy, L). Alluvial fans and shallow lakes constitute very distinctive paleoenvironments in the GBE -with the transitional environment laterally passing into both alluvial fan and lacustrine environments.

3.2.1. Alluvial fan

Near the alluvial fan apex, facies G is dominant but three subfacies are present: (1) poorly-sorted subangular to angular limestone and dolostone pebbles (only micaschists appear near the southern fringe of the basin) in a sandy or muddy matrix in beds of 0.5-1.0 m thickness, (2) normally graded and crudely stratified carbonate boulders and gravel stacked as up to 1 m-thick beds with non-erosive flat bottoms with carbonate cement and (3) red-brown sandy-gravelly lutites (Fs) stacked in beds 0.10-0.5 m in thickness containing variable amounts of scattered quartz and carbonate sand and gravel. These three subfacies of facies G are interpreted as alluvial fan proximal facies consisting of (1) debris flow, (2) sheetflow and (3) mud flow deposits (Bull, 1972; Miall, 1981; Alonso-Zarza et al., 1990; MacCarthy, 1990; Alonso-Zarza et al., 1993; Nemec and Postma, 1993).

In the Laneros alluvial fan (LAF), cut and fill channels with strongly scoured bases are commonly eroding former lacustrine deposits. These channel infills are made of single or multiple episodes of normally graded gravel sets. The total thickness of these channel infills is more than 3 m with a single erosional episode ranging from 0.2 to 1.0 m.

In some cases Facies G grades downslope to the Scb facies consisting of broad sandy bodies whose width varies from 1-15 m and the thickness of individual sets can reach 1m but the total thickness can reach 5m. Gravel clasts appear as lag deposits, some cm thick, or beds more that 1.5 m-thick. Clasts are made of carbonate rocks with schist clasts common in the southern edge of the basin. Conglomerates can be strongly carbonate or rarely gypsum-cemented and soft pebbles of mudstone or micrite are not uncommon. Sedimentary structures include massive bedding to trough cross-stratification as sets with thickness varying from some dm to more than 1m. This facies association can be interpreted as mid-toe alluvial fan deposits where incipient and mobile channel belts appeared (Friend, 1983; Cabrera et al., 1985; Alonso-Zarza et al., 1993; Nemec and Postma, 1993).

Table 1. Description of the main facies differentiated in the alluvial and lacustrine deposits of the GBE basin. Colors are from Goddard et al. (1984).
Tabla 1. Descripción de las principales facies diferenciadas en los depósitos aluviales y lacustres de la cuenca GBE. Los colores se han tomado de Goddard et al (1984).

Facies	Description/Interpretation
Gravel/ conglomerates (G)	Mesozoic carbonate rocks and metamorphic (schist, marble) clasts. Poorly to well sorted. Well or poorly (breccia) rounded. Rarely carbonate cemented. Sandy-lutitic matrix sometimes present. Color (5R 6/6, 10 R 4/6). Thickness between 0.1 m to 20m. Apex-alluvial fan
Cross bedded sand-gravel/ conglomerates (Scb)	Conglomerates contain calcareous rock fragments, usually well rounded and well sorted. Sand grains include carbonate rock fragments with variable amounts of quartz grains (lithic arenite). Fine-to coarse-grained. Parallel lamination, planar cross bedding, trough cross-bedding and ripple cross-lamination are common. 10 YR 8/2, 10 YR 8/6 colors dominate. Cement, when present, is calcite. Thickness between some decimetres to 20m. Mid-toe alluvial fan (sheet flow and channels)
Fossiliferous sands/sandstones (Sf)	Sand grains are Mesozoic carbonate rock clasts (calcarenite). Very fine to very coarse grained. Well sorted. Can show normal grading as well as parallel and ripple cross-lamination. Fossils (ostracods and foraminifera) can be dominant (bioarenite). 5 G 6/1, N5 colors. 10 YR 5/6 color when weathered. Sometimes gypsum- and/or carbonate cemented. Thickness between some decimetres to 20m. Lacustrine margin
Massive sands/sandstones (Sm)	Sand grains are Mesozoic carbonate rock clasts (calcarenite). Very fine-to very coarse-grained. Well sorted. Azoic. Sometimes gypsum- and/or carbonate-cemented. Pedogenic-carbonate accumulations. 5YR 5/6 color. Thickness ranging from some decimetres to 10 m. Lacustrine margin/sheet flow
Gypsiferous sands/sandstones (Sy)	Detrital gypsum of intrabasinal provenance (gypsarenite). Very fine-to medium-grained. Well sorted. Can show normal grading, parallel, and ripple cross-lamination. Fossils (ostracodes, gastropods) can be very abundant. Chert nodules and opalised wood. Gypsum-cemented. 5 GY 6/1 color. From some centimetres to 1 m. Central lacustrine.
Sandy/gravelly lutites (Fs)	Massive to crudely parallel laminated lutites with scattered gravel and sand. Pseudogley and bioturbation. 5 R 4/6 and 5 Y/R 5/6 colors. Thickness between some decimetres to 15 m. Transitional (sheet flow)
Massive lutites (Fm)	Massive lutites with interbedded gravel/conglomerate and sand/sandstone sheets. Carbonate or gypsum cemented. Rare terrestrial and/or freshwater gastropod shells. Ostracodes are frequent. Selenite beds. Pedogenic carbonate. N9 – 10 Y/R 8/2 color. Thickness from some centimetres to 10 m. Transitional.
Laminated lutites (Fl)	Lutites with a distinctive lamination of white-grey 1-2 mm thick lutite laminae alternations. Carbonate cemented. Selenite beds. Thickness from some centimetres to 17 metres.

	Central lacustrine
Carbonate lutites-marls (Fc)	Massive calcareous/dolomitic lutites/marls with fossils (ostracodes, gastropods) 10 y 8/2 – N9-10 YR 8/2. From some decimetres to 3 m. Lacustrine
Laminated lutites and gypsum (Fyl)	Alternating gypsum (N 9) and lutite (5 G 6/1) continous laminae 1-3 mm thick. Ostracodes are common, rare bioturbation. Rare undulating lamination. Maximum thickness 7 m. Lacustrine (central saline lake)
Lutites with displacive gypsum (Fy)	Azoic massive lutites (5 GY 4/1, N9 and 10 R 6/6) with variable amounts of randomly-oriented lenticular gypsum (10 Y/R 4/2) entombing insect larvae and ostracodes. Gypsum lenticles can reach 25 cm in diameter. From some centimetres to 3 m. Transitional (dry saline mudflat)
Massive gypsum (Ym)	Some bioturbation (burrowing) traces still visible (5 mm in diameter). 10 YR 4/2 –10 YR 8/2 colors. Secondary chert visible. From some centimetres to 8 metres. Lacustrine (central)
Dolomitic limestones and limestones (DL)	Fine-grained (micritic) with variable amounts of terrigenous (extraclasts) lutite and sand-size carbonate clasts, grainstones. Freshwater and brackish water fossil (gastropods) shells are locally very abundant. Black-brown chert concretionary aggregations are frequent. Plant stems. 5 Y 6/4, 10 Y 8/2 colors. Thickness from some centimetres to 5 metres. Shallow carbonate margin/ pond.
Dolomitic limestones and limestones with gypsum (DLy)	As DL but with variable amounts of displacive gypsum crystals which, when dissolved, originate moldic porosity. Thickness from some centimetres to 5 metres. Shallow carbonate margin/ pond.
Lignite and peaty lutites (L)	True lignite seams with still visible but rare (microscopic) phytoclasts; charcoal; phoetid black lutite beds some centimetre thick with plenty of fossil (vertebrate, gastropods and ostracodes) are common. Thickness from some centimetres to 2 m. Palustrine linked to alluvial fans and/or palustrine saline lake

3.2.2. Transitional

Typical alluvial fan facies (G and Scb) grade into red-coloured massive lutites (Fm). At the Orce and Huéscar alluvial fans (see Fig. 3), G and Scb are interbedded with very fine sand and micaceous silt. These facies are not well developed in the Cúllar Alluvial Fan because both G and Scb facies abruptly interfinger with lacustrine deposits with common scattered sand and gravel as well as bioturbation (roots) traces (Fs). These facies has been described as clay playa lake (Hubert and Hyde, 1982) or clastic playa (Kendall, 1984), but a sheet-flow linked origin cannot be discarded in some cases.

Fy is one of the most common facies in the basin: grey or brown-beige lutites. Sedimentary structures include rare parallel lamination and usually massive bedding with beds up to 2-3 m in thickness. Some bioturbation (burrowing) is present and gypsum occurs as cement or as small-sized gypsum crystals. We interpret these facies as representative of a transitional environment between the alluvial fan and shallow-lacustrine realms. In all cases lacustrine waters after evaporation, were settled and where drifted terrestrial plant remains did not arrive.

One of the best examples of palaeoenvironment (1) is the Venta Micena-1 palaeontological site (Fig 2 for location and Fig. 6 for description) where, according to Anadón et al. (1987), the palustrine sediments are dominantly made of dolostones, dolomitic marls, and black-grey lutites. The biomarkers obtained in a sample from this site (Table 2) indicate an extrabasin origin (predominant long chain alkanes represent organic matter inputs from terrestrial plants), transported through the alluvial fan channels and drifted into the lacustrine realm.

Table 2. Predominant n-alkane and long chain alkanes to short chain alkanes ratio in two GBE samples. n-C_{29} and n-C_{31} alkanes and high long chain/short chain ratios represent organic matter inputs from terrestrial plants while n-C_{17} and n-C_{19} alkanes and short long chain/short chain ratios derive from microorganisms and/or algae.

Tabla 2. n-alcano predominante y ratio de cadenas largas de alcanos respecto a cadenas corta de alcanos en dos muestras de GBE. La predominancia de alcanos n-C_{29} y n-C_{31} y ratios altos de cadenas largas de alcanos respecto a cadenas corta de alcanos refleja aportes de materia orgánica procedente de vegetación terrestre mientras que la predominancia de alcanos n-C_{17} y n-C_{19} y ratios bajos de cadenas largas de alcanos respecto a cadenas corta de alcanos reflejan aportes de materia orgánica procedente de microorganismos y/o algas.

Sample	Predominant n-alkane	Σ(n-$C_{>24}$) alkanes/ Σ(n-$C_{<23}$) alkanes
Venta Micena-1	n-C_{29} and n-C_{31}	7.75
GBES-206	n-C_{17}	0.72

Palaeoenvironment analogs for type 2 appear scattered throughout the basin lacustrine record, from the Pliocene-Pleistocene boundary to the topmost of the "composite-stratotype-section". They appear as black lutite beds, sometimes very continous, with a thickness ranging from 20 cm to 2 m; however, the associated faunal remains are brackish water gastropods and/or pelecypods. In this case organic biomarkers, as in sample GBES-206, indicate an autochthonous character being tentatively interpreted as derived from microorganisms (see Table 2).

Dolomitic limestones (DL) and dolomitic limestones with gypsum (DLy) are very common facies in the GBE basin as beds usually ranging from 2-20 cm thick with a remarkable lateral continuity. In all cases they are calcilutites strongly carbonate-cemented. Rarely they have a chalky aspect with bioturbation. Some features as karstification, brecciation, and iron and manganese stains suggest frequent subaerial exposure events. A 2-5 m-thick carbonate bed which extends over some hundreds of square kilometres in the east domain of GBE

(Orce, Galera and Cúllar localities) (Fig. 2), named the "Orce Limestone Horizon" (OLH), constitutes a wide and distinctive mesa. It consists of limestones to dolomitic limestones with a wide variety of local subfacies in the central portion of the basin. They include: i) black micritic limestones with centimetre thick bioclastic beds (lumachelle) made of freshwater gastropods shells, ii) gypsiferous limestone comprising dissolution cracks and mosaic breccia, iii) porous limestone containing moldic porosity consisting of dissolved gypsum crystal voids (0.8 mm thick), iv) lenticular tuffaceous limestones some decimetres thick, v) massive lutites with displacive gypsum (Fy) crystals (up to 10 cm) in units of variable thickness, and vi) calcareous and dolomitic marls with thicknesses varying between some centimetres to some metres. Towards the northern margin of the basin, sandy limestones (DL) and carbonate-cemented massive sandstones (Sm) appear. We interpret facies DL and DLy in the way proposed by Anadón et al (1987) as a shallow carbonate margin or pond.

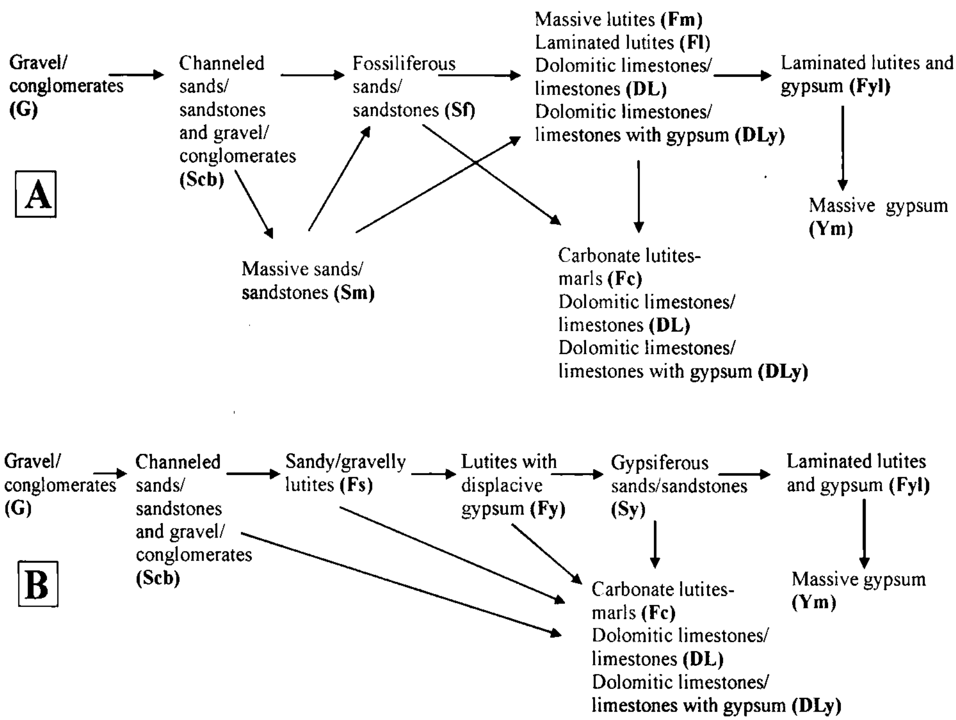


Figure 4. Facies distribution (A) in the Laneros Alluvial Fan (LAF) and (B) in Orce, Huéscar and Cúllar Alluvial Fans (OAF, HAF and CAF).

Figura 4. Distribución de facies en el Abanico Aluvial de Laneros Alluvial Fan (A) y distribución de facies en los Abanicos Aluviales de Orce, Huéscar y Cúllar (B).

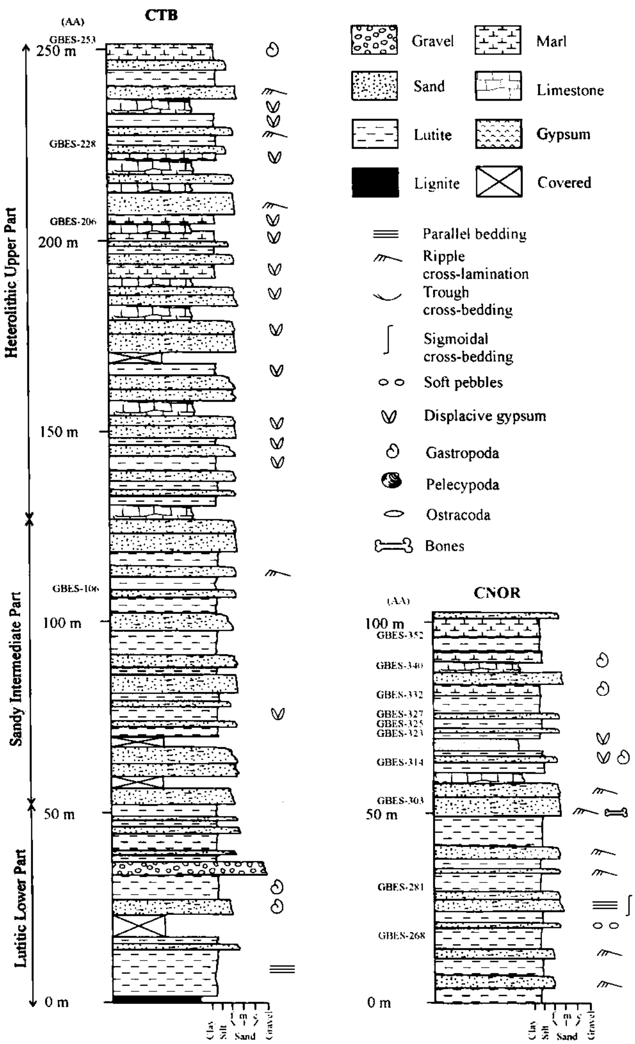


Figure 5. Cortes de Baza (CTB) and Norte de Orce (CNOR) stratigraphical sections. (AA): ostracode samples for aminoacid raceization dating.
Figura 5. Seccciones estratigráficas de Cortes de Baza (CTB) y Norte de Orce (CNOR). (AA): muestras de ostrácodos para datación por racemización de aminoácidos.

Gierlowski-Kordesch (1998) proposed that these type of carbonate beds can be explained in terms of clastic carbonate input into the marginal deposits of the lacustrine realm, as substantiated by carbonate clasts in the alluvial fan deposits. In the case of the OLH, it is evident that a dramatic hydrological change took place in the basin: the shallow lacustrine realm expanded and the alluvial fans systems shortened. In fact, accordingd to the isotopic analysis of ostracode shells (Ortiz, 2000), the OLH took place at the beginning of the "4th Colder and Wetter Period" and the lacustrine expansion event dated 404±55 to 406± 91 ky. In this mosaic-like lake, input of clastic carbonates from the source areas composed of Mesozoic carbonate rocks, occurred as suspended load and, even as bedload sediments. However, the main carbonate input was from the deeply-karstified source rocks as dissolved load. Very early diagenesis destroyed primary structures and the beds containing displacive gypsum crystals and molds can be interpreted as a result of an extremely arid period in which there was insufficient water to maintain a surface brine (Rosen, 1994) and evaporative pumping processes occurred (Hsü and Siegentaler, 1969).

Laminated lutites and gypsum (Fyl) facies occurs as alternating gypsum and grey lutite fine lamination in the central portion of GBE. Sedimentary style indicates chemical sedimentation alternating with siliciclastic input including a detrital gypsum contribution, which has been observed as very fine, even silt size, sand beds 1-3 mm thick. Lowenstein and Hardie (1985) interpreted similar halite/mud alternations as a result of dry/wet periods. This is not the case in the central portion of GBE because hollow, still articulated ostracode shells are extremely abundant, and they indicate little or no transportation as well as no diagenesis. Laminae show a remarkable lateral continuity, tens of metres, and are commonly interbedded with other facies, such as Fm and Fy, as well as with 1-4 cm-thick selenite layers. In some places laminae sets are regularly undulated due to gypsum crystal growth. Bell (1989) describes ondulated laminae in a saline lake in Chile and similar alternances have been observed in the Miocene deposits of the Tajo basin (Sanz et al, 1994; Ortí and Rosell, 2000).

Massive gypsum (Ym), is not very common in the basin. A single massive microcrystalline buff gypsum bed (thicker than 8m) occurs in the Cementerio de Galera section (Figure 6). Due to the scarcity of pure gypsum beds in the basin, this bed has been intensively mined to obtain plaster for local building purposes. Because of diagenesis processes, there is no distinctive bedding feature although some phantoms of bioturbation indicate burrowing. A brown 0.8 m-thick chert "bed" is visible at its top. In other zones we have distinguished the plaster gypsum-kiln bed ("nivel de yeseras") which consists of a brown 1 m-thick massive gypsum bed, deeply weathered, which can be followed for kilometres due to the conspicuous presence of dig holes and burned wood ash deposits.

4. THE GBE COMPOSITE "COMPOSITE-STRATOTYPE-SECTION" AND ASSOCIATED SECTIONS

In order to find a pristine lacustrine "composite-stratotype-section" containing minimal diagenesis for geochemical analyses, including amino acids and stable isotopes, we selected more marginal lacustrine deposits with the minimal effects of gypsum dissolution. Also, the Lower Pleistocene record from the Orce strait was avoided because very low sedimentation rates and low subsidence can be expected to contain sections with extensive hiati development. Therefore, the best section to perform geochemical analyses for its most continuous stratigraphy was the Cortes de Baza section (CTB, location shown in Fig.2). With the erosion of the uppermost part of this section in this part of GBE, the Norte de Orce section (CNOR) to the east was used to complete the Middle Pleistocene lacustrine "composite-stratotype section". Therefore, a 356 m-thick composite-stratotype section of the Cortes de Baza and Norte de Orce sections was obtained at the palaeo-margins of the GBE lacustrine environment. Correlation was created through field observations, palaeomagnetism studies, and the use of amino acid racemisation.

The amino acid stratigraphy (aminostratigraphy) strongly supported by paleomagnetic stratigraphy and palaeontological dates aided in establishing age boundaries. For example, the Pliocene age deposits crop out poorly in the eastern corner of the GBE (see Fig. 2) and consists of marls and micritic lacustrine limestones with common lignite seams. At this place the contact with the overlying lower Pleistocene deposits is an erosive angular unconformity which, in some places, appears underlain by chert nodules and/or by a karstified surface with a terra rossa infill of corrosion holes. In the central part of GBE, however, there is no unconformity marking the Pliocene–Pleistocene boundary, so it has been established through palaeomagnetism. The top of the GBE stratigraphical record is marked by erosive surfaces carved after the basin opening towards the Guadalquivir river valley. The GBE connection to the Guadalquivir river valley produced a general progradation of the already existing alluvial fans which first eroded and later covered the former lacustrine deposits, building a bajada which was known as "glaci" i.e. "alluvial fan piedmont" (Fig. 2).

Isotopic studies on ostracode and mollusc shells allowed Bonadonna and Leone (1989) to postulate a restricted marine origin for the sediments of the basin. It is now interpreted as a continental realm from the Lower Pliocene times (Soria, 1996).

For the description of the GBE sections we will concentrate on the composite-stratotype section. Secondary sections will complete the description of the main sedimentological aspects of the basin.

4.1. GBE Composite-Stratotype Section

4.1.1. Cortes de Baza section: UTM_{bottom}:201679; UTM_{top}:223670 (CTB)

This section is 253 m-thick (Fig. 5), extending from the east bank of the Castril river to the highest topographical point in the area (Cañada del Fraile) and was partially described by Oms et al. (1994) and Calvo Sorando (in press). For descriptive purposes we have divided this section into three different parts: 1) Lower Lutitic Part (55 m-thick), 2) Sandy Intermediate Part (75 m-thick) and 3) Upper Heterolithic Part (123 m–thick).

The most striking features of the Lutitic Lower Part are: more than 1 m-thick charcoal unit at the bottom (L), 17 m of laminated lutites (Fl) with micritic limestone (DL) intercalations, 6 m of fine-grained sandstone-calciarenites with massive lutitic intercalations (Sm-Fm), 4 m of lutites with a thin gravel layer and a black lutitic bed at the top (Fm, G, L), 2 m of massive well-rounded and poorly-sorted gravels with a lutitic matrix and a non-erosive base and flat top (G), and 16 m of lutites (Fm and Fs) with at least 12 thick-bedded and some thin or very thin-bedded calciarenites (Sm). Some sand beds are laminated. The contact between sand and overlying beds is usually horizontal.

The Sandy Intermediate Part begins with more than 17 m of calciarenites which are stacked in beds ranging from thick to very thick (Sf). Towards the top there are some lutitic intercalations (Fl and Fm). Above this part, there is an alternation of lutites (Fm) and sands- calciarenites (Sf) and gypsarenites (Sy)- with some beds of lutites with displacive gypsum (Fy).

The carbonate deposits (DL) of the Heterolithic Upper Part consist of lutitic limestones with plant stems (metre 130), micritic limestones and lutitic limestones with moldic porosity (metres 155, 185, 205, 215, 220, 240) and marls and carbonate lutites, commonly containing displacive gypsum (Fy). Sands are dominantly gypsarenites (Sy) but carbonate and/or quartz grains are also present. One of the most typical characteristics of this part of the Cortes de Baza section is the presence of displacive gypsum: enormous lenticular crystals, sometimes with a diameter up to 30 cm-long, which appear concentrated in some beds (Fy). A carbonate intra-formational breccia -result of the destruction of a former calcrete bed was also identified (metre 238).

4.1.2. Norte de Orce section: UTM_{bottom}:423770; UTM_{top}:337807 (CNOR)

The Norte de Orce section (Fig. 5) begins with 13 m of reddish fine-grained carbonate cemented sandstones (Scb) and lutites with little bioturbation and no fossil remains (Fs). Sandy bodies have planar or slightly erosive bases and ripple cross-lamination is abundant; this can be interpreted as distal alluvial fan to dry mudflat deposits. Above this there are 45 m of an alternation of gray-buff lutites (Fm-Fl) and sands (Sf) along with vertebrate remains. 0.3-3.0 m thick sand beds (Sf) are common, rarely with slightly erosive bases and with "soft pebble" lag deposits. Bed limits are underlined by lutitic laminae. Sand beds can show parallel or ripple cross-lamination and in one case (metre 26) sigmoidal cross-bedding is clearly distinguished. In the middle part of this section (metre 52) there are two beds of sands mostly massive (Sm), sometimes with ripple cross-lamination (Scb) where an extreme abundance of mica occurs but no fossils are present. Close to the top, the OLH appears as a cracked mosaic breccia of carbonate (Laznicka, 1988).

A 1.2 m thick massive gypsum bed (Ym) named "nivel de yeseras" (gypsum kiln bed) is another characteristic stratigraphical marker. Overlying the "nivel de yeseras" bed, 12 m of lutites (Fm) with some interbedded 0.2-0.6 m thick sand beds (Sf) appear. In this lutitic bed, a displacive gypsum bed (Fy), Cerastoderma shell accumulation, and sandy (Sm) seismite beds are very distinctive features. The remaining part of the section has a dominantly carbonate lutitic character (Fc) although there are 0.5-2.2 m thick interbedded sand units (Sf), sandy lutites (Fs), massive gray lutites (Fm), and two very thin lignite seams (L). There are also two lutitic beds (Fm) with abundant terrestrial and freshwater gastropod shells.

4.2. Associate Sections

The aim of this description is to offer a framework of the succession of the different facies described in the "composite-stratotype-section". For this purpose we have selected some sections from the central lacustrine facies (Cementerio de Galera, Benamaurel and East Río Baza sections) and the alluvial fan deposits-palustrine-lacustrine facies (Cúllar-Baza site, Venta Micena, San Clemente Channel and Laneros sections). The section locations are shown in Fig. 2.

4.2.1. Cementerio de Galera section: UTM_{bottom}:386776; UTM_{top}:356768 (CGAL)

The Cementerio de Galera section (Fig.6) can be considered to be representative of the transition between marginal and central lacustrine facies with some considerable fluvial influence. The section is very heterolithic because chemical lacustrine deposits appear: gypsum (Ym) and chert. Micritic dolomitic limestones (DL), silicified micrites (DL), grainstones, and gypsiferous-calcareous lutites (Fm) constitute the OLH. The main part of the section contains interbedded gypsiferous lutites (Fy) and gypsiferous sands (Sy and Scb).

4.2.2. Benamaurel section: UTM_{bottom}:276620; UTM_{top}:296605 (BEN)

This section (Fig.6) is representative of the lacustrine basin central facies where channeled sediments are not present. This section has been described in Calvo Sorando (in press). The lower part of the section consists of 12 m of interbedded gypsarenites (Sy) and massive lutites (Fm), in some cases with displacive gypsum (Fy). A 40 cm-thick bed of marly limestones (DL) is overlain by an alternation of gray lutites (Fm) and gypsiferous sands (Sy) with two-millimetre-thick bioclastic beds made of almost intact Cerastoderma disarticulated shells accumulation. The middle part of the section can be described as an alternation of composite bed sets of gypsarenites (Scb) with thin-bedded lutite intercalations (Fl-Fm). Sandy beds commonly contain horizontal and ripple-cross-lamination and are lenticularly-shaped with flat or slightly concave bases and planar or convex tops. Microselenite in lutitic beds is very common as well as enormous crystals of displacive gypsum and gypsum crusts.

In the uppermost part of this section, lutites (Fm-Fl) are dominant with rare displacive gypsum and medium- to thin-bedded detrital gypsum units (Sy).

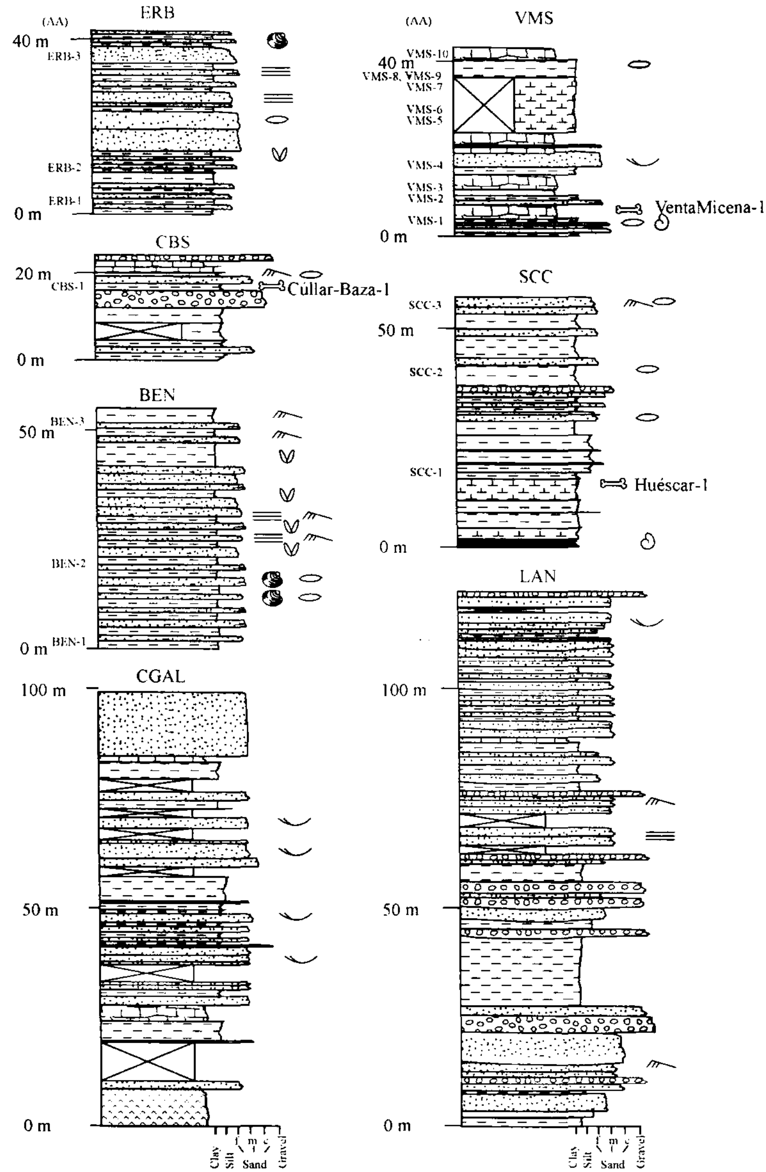


Figure 6. Cementerio de Galera (CGAL), Laneros (LAN), Benamaurel (BEN), San Clemente channel (SCC), Venta Micena (VMS), East of río Baza (ERB) and Cúllar-Baza (CBS) stratigraphical sections. (AA): ostracode samples for aminoacid racemization dating. The legend can be seen in Fig. 5.

Figura 6. Secciones estratigráficas de Cementerio de Galera (CGAL), Laneros (LAN), Benamaurel (BEN), San Clemente channel (SCC), Venta Micena (VMS), Este de río Baza (ERB) y Cúllar-Baza (CBS). (AA): muestras de ostrácodos para datación por racemización de aminoácidos. La leyenda se encuentra en la Fig. 5.

4.2.3. East of río Baza section: UTM_{bottom}:257527; UTM_{top}:278514 (ERB)

This section represents the most central lacustrine facies of the GBE basin. The visible bottom of the section consists of 7 m of beige lutites and very fine, even silt size, detrital gypsum (Fyl); the individual lamina are several mm thick and the bedding is undulatory. This detrital gypsum/lutites alternation is overlain by 7.5 m of grey lutites (Fm) with some detrital gypsum beds (Sy) and displacive gypsum (Fy). The section ends with more than 25 m of sands with parallel and ripple cross-lamination (Scb). There ostracode shells constitute bioclastic sand beds several cm or even dm thick. Several centimetre thick bioclastic beds made of almost intact Cerastoderma sp. and Corbicula sp. articulated and disarticulated shells accumulations are very common as well.

4.2.4. Cúllar-Baza palaeontological site section: UTM_{bottom}:387580; UTM_{top}:388585 (CBS)

According to Alonso-Diago (1990), the lower part of this section (Fig.6) consists of reddened poorly-sorted gravels (G) with strongly erosive bases containing calcium carbonate cement and coarse sand matrix. Pebbles are made of sedimentary and metamorphic rocks (dolostone, limestone, marble and schist). There are also thick beds of red carbonate-cemented coarse-grained sand crudely stratified or massive (Sm). Pedogenic carbonate accumulations occur as well developed beds or noduli. Near the top of the section there is an abrupt change in sedimentation with the appearance of Fc, Scb, and DL facies. Fc facies consists of 30 cm of gray-green lutites with oxidized pyrite and carbonate stains; 1m of black to light brown lutites with mammal bone remains and many freshwater gastropods and land snails intercalated with a thin-bedded white micritic limestone (DL). Scb facies consists of 2-m-thick medium-sized bioclastic sand (ostracodes) with ripple cross-lamination (climbing ripples). DL facies dominate in the upermost part of the section: 2.5 m of marlstones, marls, brown marls (Fc), and limestones (DL) which we identify as the OLH.

4.2.5. Venta Micena palaeontological site section: UTM_{bottom}:527768; UTM_{top}:516764 (VMS)

Venta Micena-1 site, one of the most important paleontological localities of the Iberian Peninsula (Martínez, 1991), is located at the base of the section.

The section (Fig.6) records the uppermost part of the Orce Alluvial Fan (OAF) of red trough cross-bedded gravels and sands (Scb) with red massive lutite intercalations (Fs) containing pseudogley, bioturbation, and root marks.

The invertebrate remains which have been used for amino acid racemisation analysis are in a 1 m-thick marly bed (Fc) with granules (gravel), charcoal, freshwater gastropods, and ostracodes. According to Anadón et al. (1987), the mammal-bearing bed is at the top of a crudely stratified, slightly lutitic limestone bed 3 m-thick, followed by 6m of partially covered lutitic limestones, marls, dolostones, and dolomitic marls (DL and Fc facies); overlain by 7 m of trough-cross-bedded gravels and sands (Scb) and 3 m of crudely stratified dolostones and limestones (DL). 17 m of the section is made of partially-covered marls (Fc). Near the top 4 m of these beige marls are extremely abundant Ammonia sp. and *Cyprideis torosa* shells. At the top the OLH is composed by ocherous micritic limestones (DL) with freshwater gastropod shells.

4.2.6. San Clemente Channel section: UTM_{bottom}:442833; UTM_{top}:455821 (SCC)

This section (Fig.6) comprises the well known and dated Middle Pleistocene Huéscar-1 palaeontological locality (Mazo et al., 1985). The Pleistocene sediments lie disconformably on very hard Pliocene micritic limestones with vug porosity and fossil freshwater molluscs which were tilted, faulted, and folded after local diapiric doming of Triassic evaporitic rocks. The lower third of the section is lutitic in character, where green and gray colours predominate over brown ones (Fm). Calcium carbonate pedogenetic concentrations form stains, small nodules, and films throughout the lutites; it is interpreted as a calcrete (Mack and James, 1993).

Near the base of the section there is a conspicuous lignite seam (L) 20-30 cm in thickness with a significant number of freshwater gastropods In this part of the section the Huéscar-1 paleontological site is located in channeled conglomerates (Scb and G) which are strongly carbonate cemented. At the top of this part of the section there is a 3 m-thick bed set of poorly-carbonate-cemented fine-grained sandstones (Sf) with sandy lutite intercalations with abundant ostracode shells (Cyprideis torosa), this bed can be traced for long distances. At its top, a 4 m-thick set of alternating yellow medium-coarse grained sandstone (Sm) and lutites (Fm) with a massive 1 m-thick gravel bed (G) at their top occurs. They are followed by 4.5 m of grey lutites (Fm) with ostracodes and white fine-grained carbonate cemented sandstone intercalations (Sm).

The top of the section comprise 10.5 m of massive green lutites with some fine-to medium-grained sand intercalations and two medium grained sand beds (Scb) with climbing ripple cross-lamination, flaser bedding, and ostracodes.

4.2.7. Laneros section: SCC: UTM_{bottom}:182733; UTM_{top}:455821 (LAN)

This section (Fig.6) is associated with the Laneros Alluvial Fan (LAF) area. Massive fine-grained material with high carbonate content are the most common (Fc), but rarely laminated (Fl), which are interpreted as being lacustrine in origin. LAN can be divided into two unequal parts. In the first 37 m, reduced colours (from a geochemical point of view) are common: white, light beige, or light green. In the remaining 90 m of the section, red or dark yellow colours are dominant with some carbonate beds. Hydromorphic (pseudogley) features are very common too. In the lower part of the section there is a very conspicuous presence of palaeochannels of (G) representing debris flow processes; each channel deeply erodes the lower muddy lacustrine sediments, with enormous flute marks visible at the channel base. Medium-sorted boulder-sized clasts are common in these channels. In the uppermost 90 m of the section, the hydrological behavior of the LAF was probably quite similar to the lowermost (reduced colour) part – perhaps only slightly different source rocks were eroded. In the uppermost third of this uppermost part of the section, very coarse carbonate-cemented sandstones with trough cross-bedding (Scb) are common, being finally overlain by an alternation of gravel (G), sand (Sm-Scb), and lutite (Fm) beds. This section has not been intensively sampled for micropaleontological analysis but the constant presence of the ostracode genera Potamocypris and Candona indicate freshwater lacustrine conditions.

5. STRATIGRAPHY

According to previously published palaeomagnetic analysis (Oms et al., 1994; Agustí et al., 1999) and our own data (Ortiz, 2000), a magnetostratigraphy of the GBE of the representative "composite-stratotype-section" (Fig. 7) has been determined. Likewise, with the aid of the amino acid racemisation method, we have established the chronostratigraphy of the GBE "composite-stratotype-section" (Ortiz, 2000 slightly modified by Ortiz et al., in prep.). For the amino acid analysis, mostly ostracodes were sampled from several horizons because they have some characteristics that make them particularly useful for amino acid racemisation dating (cf. Ortiz, 2000). Unfortunately, in the Cementerio de Galera section (CGAL), almost all the ostracode calcitic shells were totally replaced by gypsum and the amino acids were destroyed. In the LAN section, the amount of recovered valves were not enough to analyse in Gas-Chromatography (ca. 1500-2000 valves).

5.1 Palaeomagnetism

A total of 168 samples were taken for palaeomagnetic analysis from the

GBE "composite-stratotype-section". The samples were drilled and oriented in situ with a Pomeroy D-2801 portable drill. After removing the weathered surface material, cylindrical cores were prepared and measured in the Palaeomagnetism Laboratory of the Institut de Physique du Globe de Paris (IPGP), using a vertical cryogenic 2G magnetometer. All the samples were submitted to thermal demagnetisation to 600°C at steps of 50°C in a low thermal gradient PYROX oven. The magnetic susceptibility was measured at every stage with a Kappabridge KLY-2 instrument.

Samples recovered from the bottom of GBE "composite-stratotype-section" showed a palaeomagnetic polarity change from normal to reverse in metre 18 (Fig. 7), which is interpreted as the top of the Olduvai chron, that is, the Plio-Pleistocene boundary at 1.77 Ma (Cande and Kent, 1995). This interpretation was based on both the age of the Cortes de Baza palaeontological site (located approximately in metre 108 of the section) which, according to Agustí (1986), belongs to the Lower Pleistocene. The paleomagnetic data of the remaining lower part of the GBE "composite-stratotype-section" (Cortes de Baza sub-section) were previously collected by Oms et al (1994) and substantiated by Ortiz (2000). They found a negative magnetic polarity, which according to palaeontological data (Agustí, 1986), can be placed in the Matuyama Magnetozone (Lower Pleistocene).

For most of the upper part of the GBE "composite-stratotype section", a normal polarity resulted and has been interpreted as belonging to the Brunhes Magnetozone. The negative reversal found close to the top of the GBE section is assigned to either the reverse Emperor (419 ka) or Lake Biwa III (ca. 412 ka) palaeomagnetic events.

5.2 Aminostratigraphy and Aminochronology

Aminostratigraphy consists of "placing in a stratigraphical order" some geological, palaeontological, and archaeological sites in which fossils were preserved under similar environmental conditions, inorganic geochemistry, and thermal histories. To apply this method, because of their nearly ubiquitous occurrences ostracodes belonging mainly to the species *Cyprideis torosa* (Jones) (Superfamily Cytheracea) were picked in numerous sites. However in only a few cases, such as Venta Micena-1, valves belonging to other genus, Ilyocypris (Superfamily Cypridacea) and as well as *Cyprideis torosa*, had to be selected. In spite of the racemisation process being genus-dependent, these two different ostracode genera were employed to calculate the cross-calibration racemisation and epimerisation rates. In fact, in previous studies (McCoy, 1988; Oviatt et al., 1999; Kaufman, 2000), only slight differences between D/L ratios (less than 0.05 in old samples) from different phylogenetic ostracode groups (Superfamilies Cypridacea and Cytheracea) were reported.

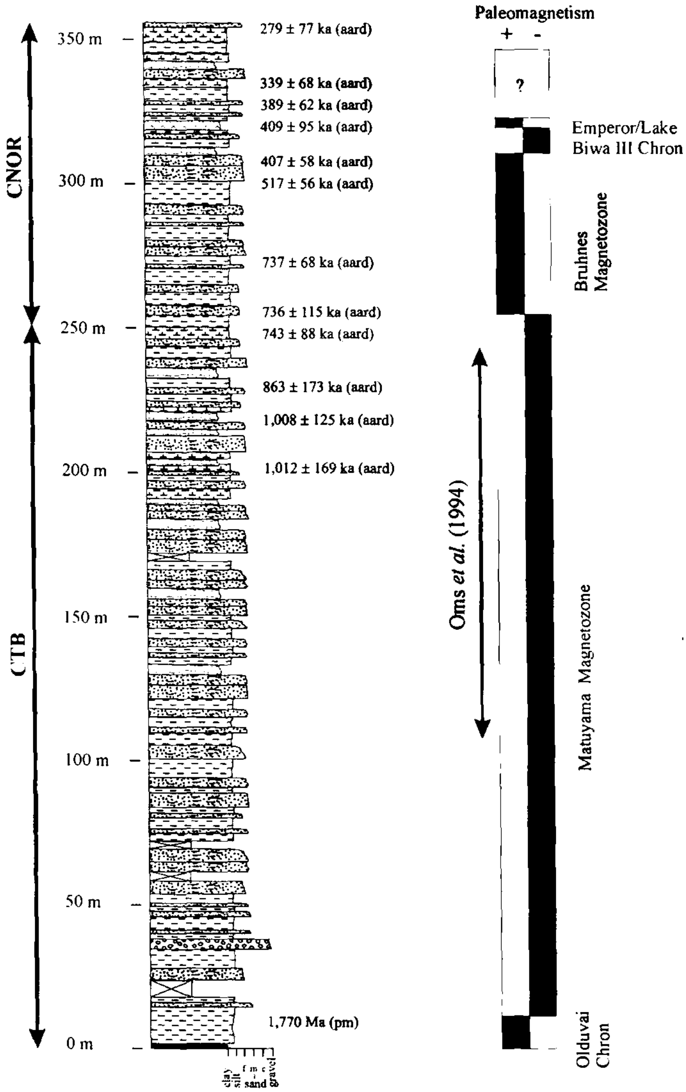


Figure 7. Chronostratigraphy (magnetostratigraphy, aminochronology and lithostratigraphy) of the GBE "composite-stratotype-section" coupled together from the CTB (Cortes de Baza section) and CNOR (Norte de Orce section). Some palaeomagnetical data are from Oms et al. (1994). Aminochronology dates are from Ortiz (2000) slightly modified in Ortiz et al. (in prep). Pm: paleomagnetism; aard: amino acid racemisation method.

Figura 7. Cronoestratigrafía (magnetoestratigrafía, aminocronología y litoestratigrafía) de las sección tipo de GBE. Algunos datos paleomagnéticos se han tomado de Oms et al. (1994). Las dataciones aminocronológicas son de Ortiz (2000) ligeramente modificadas en Ortiz et al. (in prep).

Once the samples were recovered, they were sieved under running water, dried at room temperature, and studied under a binocular microscope to determine the lithology and faunal assemblages. Ostracodes were sonicated and cleaned with water to remove sediment which might have been attached to their valves. Afterwards, we isolated 15-20 mg of the ostracodes' shells. The sample preparation protocol is described in Goodfriend (1991) and Goodfriend and Meyer (1991) and involves (1) hydrolysis under N_2 atmosphere in HCl for 20 h at 100°C and, then, desalt in HF: (2) a two step process of amino acids isolation involving first esterification with thionyl chloride in isopropanol, and second acylation by reaction with trifluoroacetic acid anhydride (25% in dichloromethane). Injections of 1-4 aliquots µl into a Hewlett-Packard 5890 gas chromatograph equipped with a Chirasil-L-Val fused silica column (0.39 mm x 0.25 µm x 25 m) from Chrompack and an NPD detector were made. Integration of the peak areas was carried out using the HP PEAK96 integration program from Hewlett-Packard. In this work, D-alle/L-Ileisoleucine, D/L Leucine, D/L aspartic acid and D/L glutamic acid ratios were chosen to establish the aminostratigraphy of the GBE basin because of their reliability. According to Torres et al. (2000), isoleucine and leucine are the most reliable ones. Kaufman (2000) used aspartic acid and glutamic acid for ostracode studies.

In order to improve the reliability of the results, samples were recovered not only in the "composite-stratotype-section" and associate sections, see figs. 5 and 6, but also in some selected sites of GBE, whose stratigraphical position was known throughout relative dating (field-work), (Table 3), and in which *Cyprideis torosa* valves were picked. For the GBE aminostratigraphy study, 112 samples were used to perform a cluster analysis, employing the euclidean distance and complete linkage (Fig. 8).

Table 3. Geographical location of ostracode samples for aminoacid racemization dating from GBE basin.
Tabla 3. Localización geográfica de muestras de ostrácodos para datación por racemización de aminoácidos de la cuenca GBE.

Sample	Coordinates (UTM)	Elevation (m)
CVA4	449769	960
LQM	419816	900
PAS	278777	865
SC	258776	890
PTR	227717	900
FN-2	521744	980
CTAR1	303728	765
CTAR2	303732	780
CTAR3	297740	815

Five aminozones were distinguished from GBE ostracode racemisation ratios, whose descriptive statistics are in Table 4. Aminozones were named from 1 to 5. These five aminozone clusters designate a "chronostratigraphical order" with the higher racemisation values at the aminozone bottom, decreasing to value toward the top of the aminozone. Slight deviations can be explained as sample error factors.

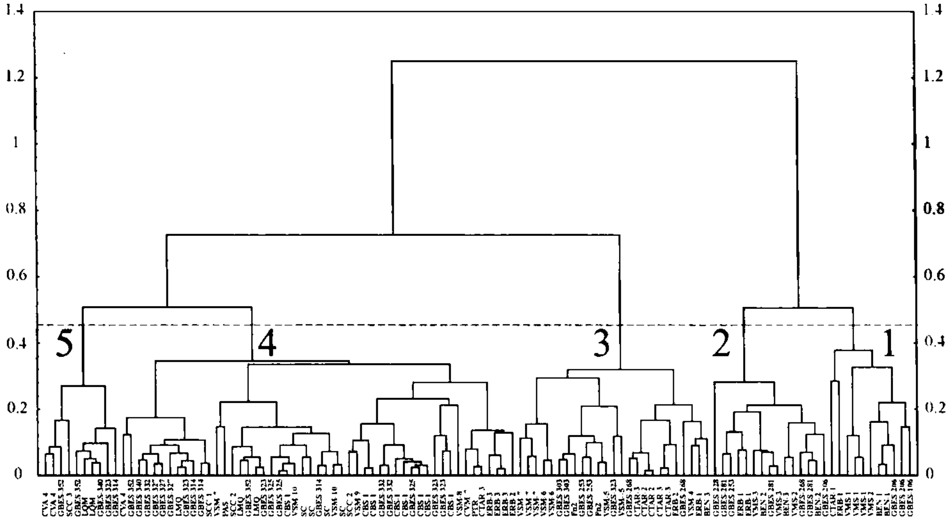


Figure 8. Similarity clusters of isoleucine, leucine, aspartic acid, and glutamic acid racemisation/epimerisation ratios of ostracode samples from GBE stratigraphical sections. Each cluster is interpreted as an aminozone.

Figure 8. Análisis cluster de los ratios de racemización/epimerización de la isoleucina, leucina, ácido aspártico y ácido glutámico en muestras de ostrácodos de las secciones estratigráficas de GBE. Los cinco grupos diferenciados representan aminozonas.

Table 4. Mean and standard deviation of isoleucine, leucine, aspertic acid and glutamic acid D/L ratios used for the ostracode aminozones differenciation in GBE (n: number of samples of each cluster).

Tabla 4. Media y desviación típica de los ratios D/L de la isoleucina, leucina, ácido aspártico y ácido glutámico D/L que caracterizan a las aminozonas de ostrácodos diferenciadas en GBE (n: número de muestras de cada grupo).

Aminozone	D-allo/L-Ile	D/L Leu	D/L Asp	D/L Glu
1 (n=11)	0.083±0.091	0.729±0.098	0.759±0.037	0.687±0.086
2 (n=15)	0.832±0.072	0.606±0.082	0.705±0.035	0.579±0.039
3 (n=25)	0.678±0.067	0.457±0.066	0.637±0.062	0.469±0.052
4 (n=51)	0.504±0.046	0.380±0.057	0.549±0.049	0.382±0.036
5 (n=10)	0.316±0.037	0.280±0.072	0.492±0.026	0.344±0.042

According to these aminozones, the stratigraphical sections were correlated with the GBE "composite-stratotype-section" as proposed in Fig. 10 where the OLH is used as a base line. The continuity of this horizon was tested through field work and confirmed by the homogeneity of aminostratigraphical data obtained in many samples taken at its lower contact. The Laneros section (LAN) was only tentatively correlated.

For age calculation, see Fig. 7, where we employed the calibrated models described in Ortiz (2000) slightly modified by Ortiz et al. (in prep.).

6. PALAEOENVIRONMENTAL INTERPRETATION

The palaeoenvironmental characteristics of a lake can be inferred from the ostracode assemblages because ostracodes have well known environmental tolerance ranges, e.g. salinity (Anadón et al., 1994).

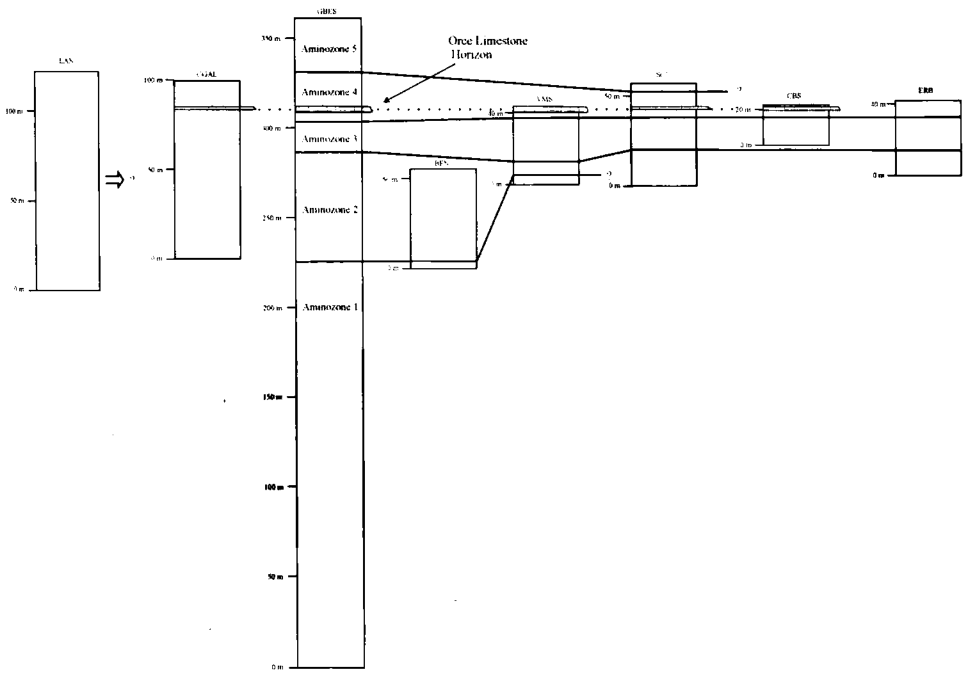
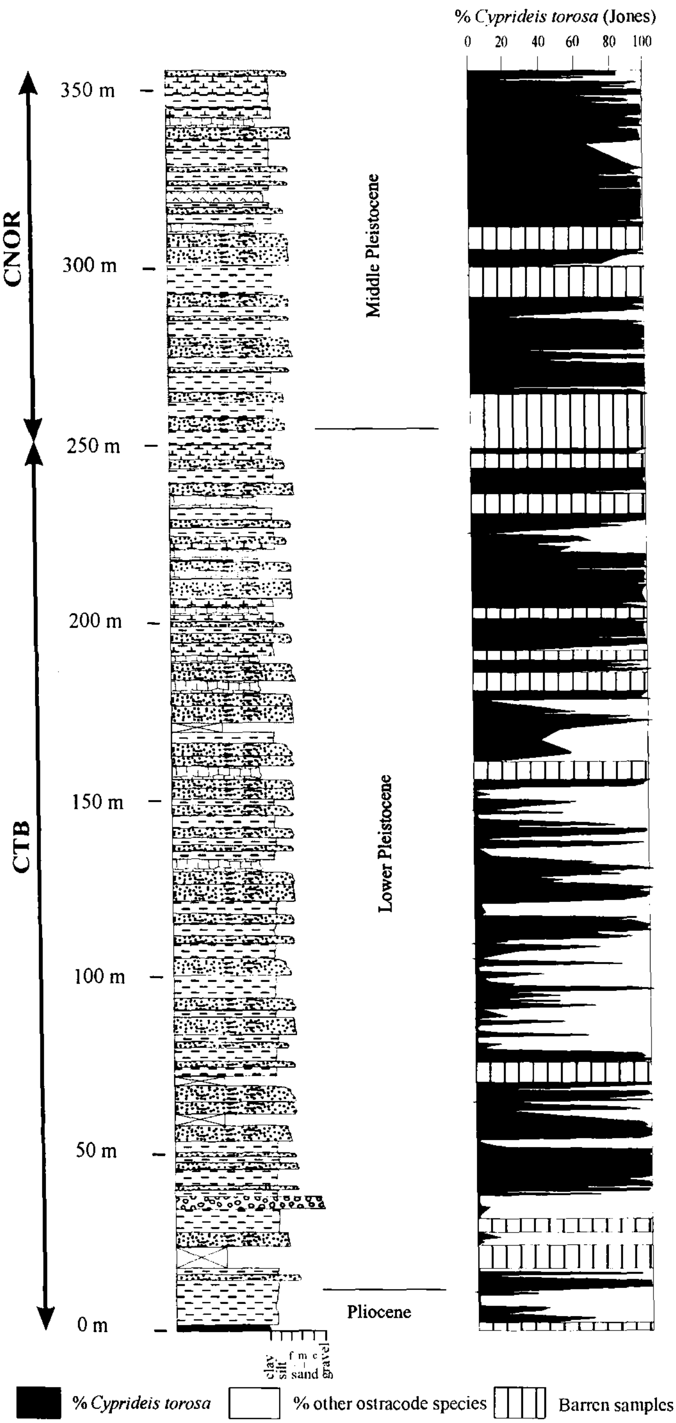


Figure 9. Aminostratigraphical and lithostratigraphical correlation of the stratigraphical sections of GBE. Note that LAN cannot be exactly correlated due to lack of data.
Figura 9. Correlación aminoestratigráfica y litoestratigráfica de las secciones estratigráficas de GBE.

The presence of abundant ostracode shells in the sediments of the GBE "composite-stratotype-section" indicates a dominant lacustrine environment. The most common representative is *Cyprideis torosa* (Jones) that colonizes waters with a wide range of salinity which can vary from 0.5 $^0/_{00}$ to 140 $^0/_{00}$ (cf. De Deckker, 1981; Carbonel, 1983). When salinity is high, it can be the only species remaining, constituting monospecific bioclastic accumulations (ostracodite), or it may appear to be associated with other high salinity biomarkers such as other ostracodes (Loxoconcha minima and Leptocythere castanea), the pelecypod Cerastoderma sp, and foraminifera (Ammonia sp) (Gasse et al., 1987). In these cases we interpret the sedimentation was produced in a high salinity lake. In fact, according to Anadón (1989), the presence of thalassic fauna, as those cited above, suggests the existence of oligohaline to hyperhaline waters. However, at low or moderate salinities, *Cyprideis torosa* (Jones) is found together with other ostracode species, mainly representatives of the Candona, Ilyocypris and Potamocypris groups, and usually constitutes less than 50% of the valves contained in a sample. The occurence of some lower salinity tolerant ostracodes suggests periods of significant freshwater input.

A total of 674 samples were recovered approximately at 40-50 cm intervals along the GBE "composite-stratotype-section" in order to determine the ostracode species and their percentages. We decided to take a sample each 40-50 cm because of the calculated sedimentation rate, 22 cm/ka (Ortiz, 2000). When the percentage of *C. torosa* in a sample is very high, sometimes reaching 100%, the salinity would be high, in contrast to samples with small percentages designating freshwater or slightly saline waters. Thus, we have plotted the percentage of *Cyprideis torosa* valves recovered in the samples in Fig. 10, which we relate to the salinity of the lacustrine environment. According to the ostracode genera distribution, even in the selected areas of the "composite-stratotype-section" located in a marginal zone of the central saline lacustrine realm, high salinity conditions prevailed over low salinity ones. However a noticeable distinctive hydrological behavior can be observed between metres 75 and 175 of the CTB subsection where low salinity ostracodes dominated. This fact suggests that during most of the Lower Pleistocene, a high frequency alternation of dry and humid conditions occurred, most likely linked to the Laneros Alluvial Fan (LAF) hydrological regimes. This cannot be interpreted as a change in the source rock because it remained unchanged over time, and only small neotectonic events affected the area during the Pleistocene. With some scarce exceptions (or coincidences) high or low palaeosalinities cannot be correlated to a specific sediment grain size. Sandy or lutitic sediments may contain dominantly high salinity biomarkers (*C. torosa*) or not. In some parts of the "composite-stratotype-section", ostracodes are lacking because of low preservation or incompatible palaeoconditions, as in red alluvial fan sediments or sandy beds at the bottom of the CTB subsection corresponding to the Laneros Alluvial Fan channel deposits, or sand flat areas. In some other cases, as ostracode barren lutites and sands the presence of large quantities of displacive gypsum, suggest a



dry period which did not allow ostracode development. The presence of mummified ostracodes or insect larvae inside the displacive gypsum crystals which were lacking in the mudstone matrix, indicates that only localized micro-ponds occurred at these maximum dry periods.

Figure 10. Paleosalinity evolution based on the percentages of *Cyprideis torosa* (black) vs. other ostracode species (white) in the GBE "composite-stratotype-section".
Figura 10. Evolución de la paleosalinidad basada en los porcentajes de *Cyprideis torosa* (en negro) respecto a otras especies de ostrácodos (en blanco) en la sección tipo.

The high salinity of lacustrine water in the CNOR stratigraphical subsection must be interpreted taking into account its singular palaeogeographical situation: a narrow corridor developed between two sierras fed by an alluvial fan with its catchment located on soft Cainozoic marine rocks containing gypsum. Furthermore, in the Orce and Huéscar area, saline springs are still active and the "trail" of an ancient palaeospring at the east of Huéscar has been clearly mapped by Vera (1970a).

CONCLUSIONS

A stratigraphical "composite-stratotype-section" mainly composed by sandy and lutitic sediments has been described in the lacustrine margin of the GBE basin. According to palaeomagnetic studies and amino acid racemisation ratios, the stratigraphical "composite-stratotype-section" covers a time span between the Pliocene-Pleistocene boundary (1.77 Ma) and the upper part of the Middle Pleistocene (ca. 300 ka). In this section a very important event of lacustrine expansion, the "Orce Limestone Horizon", is defined (and dated) as an isochron and allows the correlation of palaeobiological (palaeontological sites), palaeoanthropological (Lower and Middle Palaeolithic sites) and neotectonic (seismites) events. The stratigraphical "composite-stratotype-section" has been placed in the basin facies framework to define unconformities so as to establish palaeogeographical realm and facies relationships. Four main alluvial fans, Laneros, Huéscar, Orce and Cúllar, and their catchments, played a decisive role in the definition of the basin boundaries. Another important unconformity was created in the Venta Micena-Orce realm, where neotectonics tilted and folded former Pliocene lacustrine deposits, reinforcing the low sedimentation rates during the Lower Pleistocene times. Fossil shells of mainly ostracode representatives appeared in almost all the samples taken along the stratigraphical "composite-stratotype-section". Based on *Cyprideis torosa* (Jones), a saline water ostracode, abundance as well as the presence of foraminifera, a lacustrine salinity variation has been established. Because of the lack of a stratigraphical record in the western realm of GBE due to erosion, and the possible development of hiati in the eastern part, two subsections have been used to compose the stratigraphical "composite-stratotype-section". It is noteworthy that during the lower half of the lower part of the Lower Pleistocene, the recorded salinity variation exhibits strong and frequent changes while during the remaining Lower Pleistocene stratigraphical record, high salinity conditions prevailed. The Middle Pleistocene salinity record was studied in a restricted part of the basin, the Orce strait, which showed a dominance of high salinity palaeoconditions stable trough-time. This implies that possible climatic changes were not recorded in the ostracode record of this part of the basin, because tectonic-linked influence (diapirism and gypsum dissolution) masked any possible paleosalinity fluctuations induced by climate variability. On the other hand, a constant high salinity could have been maintained through time because of the local hydrologic conditions (Rosen, 1994).

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BIBLIOGRAPHY

Alonso Diago, M.A., 1990. El Plio-Pleistoceno de la Cuenca de Guadix-Baza (zona occidental y área de Cúllar-Baza): Estratigrafía, sedimentología y evolución paleogeográfica, tafonomía de yacimientos de vertebrados. Ph.D.Dissertation, University of Salamanca, Spain, 561 pp.

Alonso-Zarza, A.M., Calvo, J.P., García de Cura, M.A., Hoyos, M., 1990. Los sistemas aluviales miocenos del borde noroeste de la Cuenca de Madrid: sector Cifuentes-Las Inviernas (Guadalajara). Revista de la Sociedad Geológica de España 3, 213-229.

Alonso-Zarza, A.M., Calvo, J.P., García de Cura, M.A., 1993. Palaeogeomorphological controls on the distribution and sedimentary styles of alluvial systems, Neogene of the NE of the Madrid basin (central Spain). In Marzo, M., Puigdefábregas, C. (Eds.). Alluvial Sedimentation. International Association of Sedimentologists, Special Publication 17, pp 277-292.

Agustí, J., 1986. Synthèse biostratigraphique du Plio-Pléistocène de Guadix-Baza (Province de Granada, Sud-est de l'Espagne. Geobios 19 (4), 505-510.

Agustí, J., Oms, O., Parés, J.M., 1999. Calibration of the Early-Middle Pleistocene transition in the continental beds of the Guadix-Baza Basin (SE Spain). Quaternary Science Review 18, 1409-1417.

Anadón, P., 1989. Los lagos salinos interiores (atalásicos) con faunas de afinidad marina del Cenozoico de la Península Ibérica. Acta Geológica Hispánica 24, 83-102.

Anadón P., Juliá R., De Dekker P., Rosso J.C., Soulié-Märsche I., 1987. Contribución a la paleolimnología del Pleistoceno inferior de la cuenca de Baza (Sector Orce-Venta Micena). In: Agustí, J. (Ed.), Geología y Paleontología del Pleistoceno inferior de Venta Micena, Instituto de Paleontología Miquel Crusafont, Memoria Especial I, pp. 35-72.

Anadón, P., Utrilla, R., Julià, R., 1994. Palaeoenvironmental reconstruction of a Pleistocene lacustrine sequence from faunal assemblages and ostracode shell geochemistry, Baza Basin, SE Spain. Palaeogeography, Palaeoclimatology, Palaeoecology 111, 191-205.

Banerjee, I., Kidwell, S.M., 1991. Significance of molluscan shell beds in sequence stratigraphy: an example from the Lower Cretaceous Manville Group of Canada. Sedimentology 38 (5), 913-934.

Banks, C.J., Warburton, J., 1991. Mid-crustal detachment in the Betic system of southeast Spain. Tectonophysics 191, 275-289.

Bell, C.M., 1989. Saline lake carbonates within an Upper Jurassic-Lower Cretaceous continental red bed sequence in the Atacama region of northern Chile. Sedimentology 36 (4), 651-664.

Blair, T.C., MacPherson, J.G., 1994. Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes and facies assemblages. Journal of Sedimentary Research A64, 450-589.

Bonadonna, F.P., Leone, G., 1989. La Región de Guadix-Baza: datos de la composición isotópica del oxígeno y del carbono y reconstrucción paleoambiental. In: Alberdi M.T., Bonadonna, F.P. (Eds.), Geología y Paleontología de la cuenca de Guadix-Baza, Trabajos sobre Neógeno-Cuaternario (CSIC), 11: 79-98.

Bull, W.B., 1972. Recognition of alluvial fans deposits in the stratigraphic record. In: Rigby, K., Hambin, K. (Eds.), Recognition of ancient sedimentary environments. Society of Economy, Paleontology and Mineralalogy, Special Publication 16, pp 63-83.

Cabrera, Ll., Colombo, F., Robles, S. (1985). Sedimentation and Tectonics interrrelationships in the Paleogene marginal alluvial fans of the SE Ebro basin. Transition from alluvial to shallow lacustrine environments. In: Rosell, J., Milá, M. (Eds.), 6th European IAS Meeting in Lérida, Spain. Excursion guidebook 10, pp. 394-492.

Calvo Sorando, J.P., in press. Mapa geológico Magna, 1:50.000 Cúllar-Baza (972). Instituto Geológico y Minero de España. Documentación complementaria inédita (in press).

Cande S.C., Kent, D.V., 1995. Revised calibration of the geomagnetic polarity time scale for the late Cretaceous and Cenozoic. Journal of Geophysical Research 100, 6093-6095.

Carbonel, G., 1983. Morphométre et hypersalinité chez Cyprideis torosa (Jones) (Ostracoda, Actuel) dans les salines de Santa-Pola (Alicante, Espagne). Sciences Géologiques Bulletin 36 (4), 211-219.

Collinson, J.D., 1996. Alluvial sediments. In Reading H.G. (Ed.), Sedimentary Environments: Processes, Facies and Stratigraphy. Blackwell Science, Oxford, pp. 37-82

De Deckker, P., 1981. Ostracods of athalassic saline lakes. Hydrobiologia 81, 131-144.

Friend, P.F., 1983. Towards the field classification of alluvial architecture or sequence. In: Collison, J.D., Lewin, J.) Modern and Ancient Fluvial Systems. Special. Publications of the International Association of Sedimentologists 6, pp 345-354.

Gasse, F., Fontes, J.C., Plaziat, J.C., Carbonel,P., Kaczmarska, I., De Deckker, P., Soulié-Marsche, I, Callot, Y. y Dupeuble, P.A., 1987. Biological remains, geochemistry and stable isotopes for the reconstruction of environmental and hidrological changes in the

Holocene lakes from North Sahara. Paleogeography, Paleoclimatology, Paleoecology 60, 1-46.

Gibert, J., Arribas, A., Martínez Navarro, B., Albadalejo, S., Gaete, R., Gibert, L., Peñas, C., Torrico, R., 1992. Síntesis cronoestratigráfica del Pleistoceno inferior de la región de Orce. In: Gibert, J. (Ed), Presencia humana en el Pleistoceno inferior de Granada y Murcia. Proyecto Orce-Cueva Victoria (1988-1992). Museo de Prehistoria Josep Gibert, Granada, pp. 107-114.

Gierlowski-Kordesch, E.H., 1998. Carbonate deposition in an ephemeral siliciclastic alluvial system: Jurassic Shuttle Meadow Formation, Newark Supergroup, Hartford Basin, USA. Palaeogeography, Palaeoclimatology, Palaeoecology 140: 161-184.

Goddard, E.N., Trask, P.D., Ford, R.K., Rove, O.N., Singewald, J.T., Overbeck, R.M., 1984. Rock-Color Chart. Geological Society of America.

Goodfriend, G.A., 1991. Patterns of racemization and epimerization of amino acids in land snail shells over the course of the Holocene. Geochimica et Cosmochimica Acta 55, 293-302.

Goodfriend, G.A., Meyer, V., 1991. A comparative study of the kinetics of amino acid racemization/epimerization in fossil and modern mollusc shells. Geochimica et Cosmochimica Acta 55, 3355-3367.

Hanford, C.R., 1982. Sedimentology and evaporative genesis in a Holocene continental sabkha playa basin, Bristol Dry Lake, California. Sedimentology 29, 239-253.

Hardie, L.A., Smoot, J.P., Eugster, H.P., 1978. Saline lakes and their deposits. In: Matter, A., Tucker, M.E. (Eds.) Modern and Ancient Lake Sediments. Special Publication of the International Association of Sedimentologists 2, pp 7-41.

Hubert, J.F., Hyde, M.G., 1982. Sheet-flow deposits of graded beds and mudstones on an alluvial sandflat-playa system: Upper Triassic Blomidon redbeds, St Mary's Bay, Nueva Scotia. Sedimentology 29, 457-474.

Hsü, K.J., Siegentaler, C., 1969. Preliminary experiment on hydrodynamic movements induced by evaporation and their bearing on the dolomite problem. Sedimentology 12, 11-25.

IGME, 1988. Exploración de lignitos en la cuencas terciarias del ámbito bético. Instituto Geológico y Minero de España, Madrid (inédito), 320 p.

Kaufman, D.S., 2000. Amino acid racemization in ostracodes. In: Goodfriend, G.A., Collins, M.J., Fogel, M.L., Macko, S.A., Wehmiller, J.F. (Eds.), Perspectives in Amino Acids and Protein Geochemistry. Oxford University Press, New York. pp. 145-160.

Kendall, A.C., 1984. Evaporites. In: Walker, R.G. (Ed.), Facies Model. Geoscience Canada 1, pp 259-296.

Laznicka P., 1988. Breccias and coarse fragmentites: petrology, environments, associations, ores. Developments in Economic Geology 25. Elsevier, New York, pp 832.

Lowenstein, T.K., Hardie, L.A., 1985. Criteria for the recognition of salt-pan evaporites. Sedimentology 32: 627-644.

MacCarthy, I.A.J., 1990. Alluvial sedimentation patterns in the Munster Basin, Ireland. Sedimentology 37 (4), 685-712.

Mack, G.H., James, W.C., 1993. Control of basin symmetry on fluvial lithofacies, Camp Rice and Palomas Formations (Plio-Pleistocene), southern Rio Grande Rift, USA. In:

Marzo, M., Puigdefábregas, C. (Eds.), Alluvial Sedimentation. International Association of Sedimentologists, Special Publication 17, pp. 439-450.

Martínez, B., 1991. Revisión sistemática de la fauna de macromamíferos del yacimiento de Venta Micena (Orce, Granada). In: Gibert, J. (Ed), Presencia humana en el Pleistoceno inferior de Granada y Murcia. Proyecto Orce-Cueva Victoria (1988-1992). Museo de Prehistoria Josep Gibert, Granada, pp 21-85.

Mazo, A.V., Sesé, C., Ruiz Bustos, A., Peña, J.A., 1985. Geología y paleontología de los yacimientos Plio-Pleistocenos de Huéscar (Depresión de Guadix-Baza, Granada). Estudios Geológicos 41, 467-493.

McCoy, W.D., 1988. Amino acid racemization in fossil non-marine ostracod shells: a potential tool for the study of Quaternary stratigraphy, chronology and palaeotemperature. In De Deckker, P., Colin, J.P., Peypouquet J.P. (Eds.), Ostracoda in the Earth Sciences. Elsevier, Amsterdam & New York. pp. 201-218.

Miall, A.D., 1981. Alluvial sedimentary basins: tectonic setting and basin structure. In: Miall, A.D. (Ed.), Sedimentation and tectonics in alluvial basins. Geological Association of Canada, Special Paper 23, pp. 1-33.

Nemec, W., Postma, G., 1993. Quaternary alluvial fans in Crete. In Marzo, M., Puigdefábregas, C. (Eds.), Alluvial Sedimentation. International Association of Sedimentologists, Special Publication, pp 235-276.

Oms, O., Garcés, M., Parés, J.M., Agustí, J., Anadón, P., Julià, R., 1994. Magnetostratigraphic characterization of a thick Lower Pleistocene lacustrine sequence from the Baza Basin (Betic Chain, Southern Spain). Physics of the Earth and Planetary Interiors 85, 173-180.

Ortí, F., Pueyo, J.J., Geisler-Cussey, D., Dulau, N., 1984. Evaporitic sedimentation in the coastal salinas of Santa Pola (Alicante, Spain). Revista del Instituto de Investigaciones Geológicas. Diputación de Barcelona 38-39, 169-220.

Ortí, F., Rosell, L., Utrilla, R., Inglés, M., Pueyo, J., Pierre, C., 1988. Reciclaje de evaporitas en la Península Ibérica durante el ciclo alpino. II Congreso Geológico de España 1, 421-424.

Ortí, F., Rosell, L., 2000. Evaporative systems and diagenetic patterns in the Calatayud Basin (Miocene, central Spain). Sedimentology 47 (3), 665-685.

Ortiz, J.E., 2000. Evolución paleoclimática durante el Pleistoceno de la mitad sur de la Península Ibérica mediante el estudio paleontológico y geoquímico de ostrácodos de la cuenca de Cúllar-Baza (Granada, España). Ph.D. Dissertation, Politechnical University of Madrid, Spain, 4 vol., 567 pp.

Ortiz, J.E., Torres, T., Delgado, A., Julià, R., Llamas, F.J., Soler, V., in prep. Numerical dating algorithms of amino acid racemization ratios analyzed in continental ostracodes of the Iberian Peninsula (Spain). Application to Guadix-Baza basin (Andalusia, southern Spain).

Oviatt, C.G., Thompson, R.S., Kaufman, D.S., Bright, J., Forester, R.M., 1999. Reinterpretation of the Burmester core, Bonneville Basin, Utah. Quaternary Research 52, 180-184.

Peña, J.A., 1985. La Depresión de Guadix-Baza. Estudios Geológicos 41, 33-46.

Pous, J., Queralt, P., Ledo, J.J., Roca, E., García, X., Marcuello, A., 1995. Electrical conductive structure of the central Betics from magnetotelluric data. Revista de la Sociedad Geológica de España 8 (4), 513-517.

Rodríguez-Aranda, J.J., Calvo, J.P., Ordóñez, S. 1991. Transición de abanicos aluviales a evaporitas en el Mioceno del borde oriental de la cuenca de Madrid (sector Barajas de Melo-Illana). Revista de la Sociedad Geológica de España 4 (1-2), 33-50.

Rosen, M.R., 1994. The importance of groundwater in playas: a review of playa classifications and the sedimentology and hydrology of playas. In (Rosen, M.R., Ed), Paleoclimate and Basin Evolution of Playa Systems. Geological Society of America, Special Paper 289, pp. 1-8.

Sanz, M.E., Rodríguez-Aranda, J.P., Calvo, J.P., Ordóñez, S., 1991. Sedimentología de las facies de yesos detríticos de la Unidad Intermedia del Mioceno (sector sur de la Cuenca de Madrid). Congreso Español del Terciario de Vic 1, 316-319.

Sanz, M.E., Rodríguez-Aranda, J.P., Calvo, J.P., Ordóñez, S., 1994. Tertiary detrital gypsum in the Madrid basin, Spain: Criteria for interpreting detrital gypsum in continental evaporitic sequences. Sedimentology and Geochemistry of Modern and Ancient Saline Lakes, SEPM Special Publication 50, 217-228.

Soria, J.M., 1996. Historia de la subsidencia y levantamiento en el margen norte de la cuenca intramontañosa de Guadix (Cordillera Bética central). Geogaceta 20 (2), 464-467.

Soria, F.J., López-Garrido, A.C., Vera, J.A., 1987. Análisis estratigráfico y sedimentológico de los depósitos neógeno-cuaternarios en el sector de Orce (depresión de Guadix-Baza). Paleontologia i Evolució. Memoria especial 1, 11-34.

Torres, T, Llamas, J., Canoira, L., Coello, F.J., García-Alonso, P., Ortiz, J.E., 2000. Aminostratigraphy of two Pleistocene marine sequences from the Mediterranean Coast of Spain: Cabo de Huertas (Alicante) and Garrucha (Almería). In Goodfriend, G.A., Collins, M.J., Fogel, M.L., Macko, S.A., Wehmiller, J.F. (Eds.) Perspectives in Amino Acids and Protein Geochemistry. Oxford University Press, New York. pp. 263-278.

Vera, J.A., 1969 Características estratigráficas de la serie de Baza (Depresión de Guadix-Baza). Acta Geológica Hispánica, IV (1), 14-17.

Vera, J.A., 1970a. Facies del Plioceno de la Depresión de Guadix-Baza. Cuadernos Geológicos de la Universidad de Granada 1, 23-25.

Vera, J.A., 1970b. Estudio estratigráfico de la Depresión de Guadix-Baza. Boletín del Instituto Geológico y Minero de España 81, 429-462.

Vera, J.A., Fernández, J., López-Garrido, A.C., Rodríguez-Fernández, J., 1984. Geología y estratigrafía de los materiales plioceno-pleistocenos del sector de Orce-Venta Micena (Prov. Granada). Paleontologia i Evolució 18, 3-11.

Yagmurlu, F., Helvacì, C., 1994. Sedimentological characteristics and facies of the evaporite-bearing Kimir Formation (Neogene), Beypazarì Basin, central Anatolia, Turkey. Sedimentology 41 (5), 847-860.